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PROJECTED AMAZONIAN DEFORESTATION IN THE 21TH CENTURY AND POSSIBLE REGIONAL CLIMATIC IMPACTS

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1. INTRODUCTION

In the last years, many authors have discussed the possible effects of tropical deforestation on global climate processes. Many AGCM modeling studies have considered the sensitivity of the climate system to a complete conversion of Amazonian rainforests to pastures (Dickinson and Henderson-Sellers, 1988; Nobre et al., 1991, Henderson-Sellers et al., 1993). Most of these studies have showed the importance of the tropical rainforests for the Earth's climate. The climate of Amazonia is responding to two concurrent perturbations: rapid rates of land-use change, mostly conversion of forest to pasture or cropland, and global warming. Field observations (Gash and Nobre, 1997) and numerical studies (e.g. Nobre et al., 1991) reveal that large scale deforestation in Amazonia could alter the regional climate significantly. Evapotranspiration is reduced and surface temperature is increased for pastures.

The present work evaluates the impacts of the conversion of Amazonia rainforest to pasture, using four distinct scenarios from Soares-Filho (2004) for years: 2025, 2050 and 2100. In all cases, the deforested areas are replaced by degraded grass (pasture). Additionally there is another scenario when all Amazon forest is replaced by degraded grass. We have used CPTEC global atmospheric model to assess the effects of projected Amazonian deforestation in the 21th century on the regional climate.

2. MODEL DESCRIPTION AND EXPERIMENT DESIGN

The CPTEC global atmospheric model (Cavalcanti et al. 2002, Kinter et al. 1997) is used for the numerical simulations. Model resolution is T062L28, that is, 28 levels and horizontal resolution of about 2°. The land surface scheme within the CPTEC AGCM is the SSiB (Xue et al., 1991). For each land grid point, a vegetation type (biome) is prescribed, and the vegetation classification follows Dorman and Sellers (1989). A set of physical, morphological, and physiological parameters is assigned to each biome. Based on Nobre (1991), Xue et al. (1996), Rocha (2001) and ABRACOS experiment (Gash et al. 1996) we created a new vegetation type called degraded grass (pasture). In the simulations of deforestation, the deforested areas are replaced by degraded grass. The CPTEC model was integrated for each experiment and control for 62 months and with the initial condition of 12Z 15 October 2002 from NCEP. We used climatological boundary conditions, including sea surface temperature, for experiments and control. In the present work, the assessment of climate impacts is based on anomaly values (i.e., difference between simulation and control runs). Due to the existence of systematic errors, it is necessary to assign uncertainties to the calculated anomalies (Oyama and Nobre, 2004). The first 26 months of each integration are neglected due the soil moisture spin up. The results are the mean of the last 36 months (experiment – control).

The numerical simulations evaluated the impacts of the conversion of Amazonia rainforest to pasture, using four distinct scenarios: 1) land cover scenario for year 2025 (~28% deforested area - from Soares-Filho, 2004); 2) scenario for year 2050 (~45% deforested area); 3) scenario for year 2100 (~67% deforested area) and 4) replace all the Amazonia rainforest by pasture (deforested case). Figure 1 shows the land cover scenarios. The resulting simulated fields are compared to investigating the effects of changing the vegetation in Amazonian.

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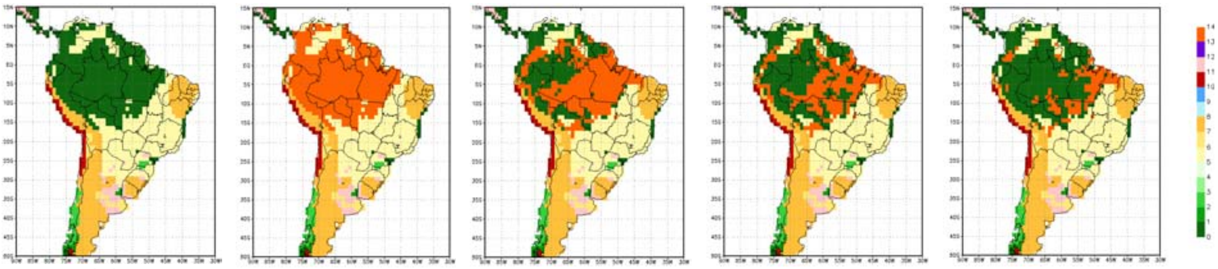
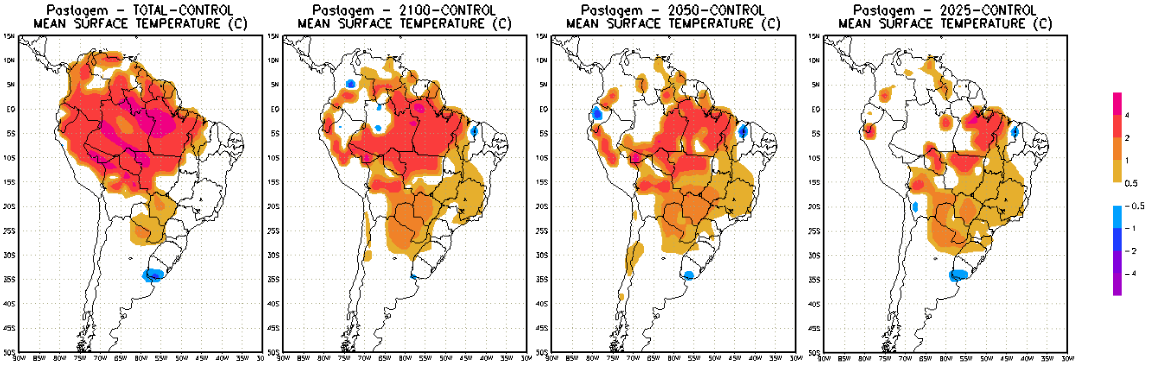


(a) (b) (c) (d) (e)

Figure 1 – Distribution of SSiB vegetation types over South America on a 1° by 1° long grid. (a) control case; (b) deforested case; (c) land cover scenario for year 2100; (d) land cover scenario for year 2050; (e) land cover scenario for year 2025. 1 – broadleaf evergreen trees (tropical forest), 2 – broadleaf deciduous trees, 3- broadleaf and needleleaf trees (mixed forest), 4 – needleleaf evergreen trees (boreal forest), 5- needleleaf deciduous trees (larch), 6 – broadleaf trees with groundcover (savanna), 7 – groundcover only (grasslands), 8 – broadleaf shrubs with perennial groundcover (caatinga), 9 – broadleaf shrubs with bare soil (semi-desert), 10 – dwarf trees and shrubs with groundcover (tundra), 11 – bare soil (desert), 12 – cultivated land represented by wheat, 13 – perpetual ice, 14 - degraded grass (pasture).

3. RESULTS

The results shows warmer surface temperature in all deforestation cases compared to the control case (Figure 2). In general, there is an increase in the surface temperature about 0.8°C for 2025 experiment, 1.6°C for 2050 experiment, 2.1°C for 2100 and 2.5°C for deforested case. These values are to area: 6°S-6°N / 63°W-45°W (Figure 3) for annual average. For the scenario where there is a complete conversion of Amazonia rainforest to pasture there are some areas warmer than 4°C. This relative warming of the deforested land surface is consistent with the reduction in evapotranspiration (Figure 4) and the lower surface roughness length. Evapotranspiration was reduced by ~360 – 730 mm/day in the deforestation case and in area 6°S-6°N / 63°W-45°W this decrease is about that 16.1% relative to the control case (Figure 4). In the other experiments the evapotranspiration was reduced by 4.4% for 2025 experiment, 7.8% for 2050 and 11% for 2100 experiment relative to the control case. To partially compensate for the decrease in evapotranspiration (latent heating), sensible heat fluxes increased by about 35% (~13 W m^{-2}) in the deforestation case relative to the control case, 14% in the 2025 experiment, 9% in the 2050 experiment and 26% in the 2100 experiment relative to the control case.



(a) (b) (c) (d)

Figure 2 – Mean surface temperature differences (°C) between 12-month means (January to December) of deforestation and control cases (deforested – control) for South America: (a) deforestation case – control; (b) 2100 experiment – control; (c) 2050 experiment – control; (d) 2025 experiment – control.

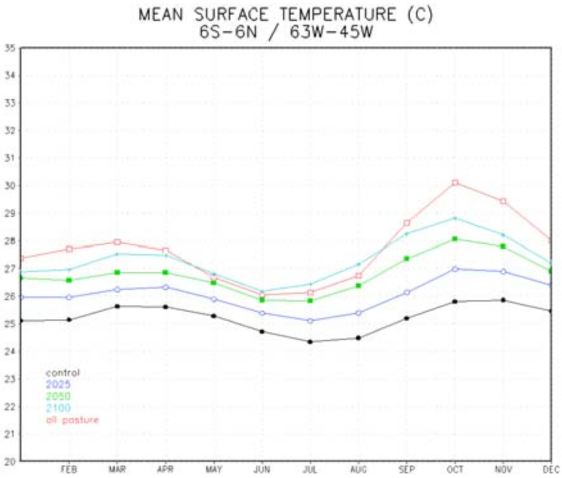
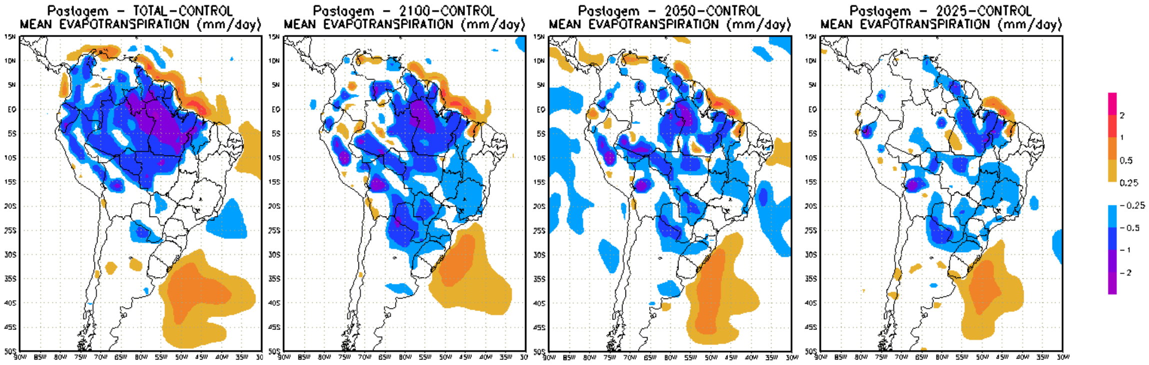


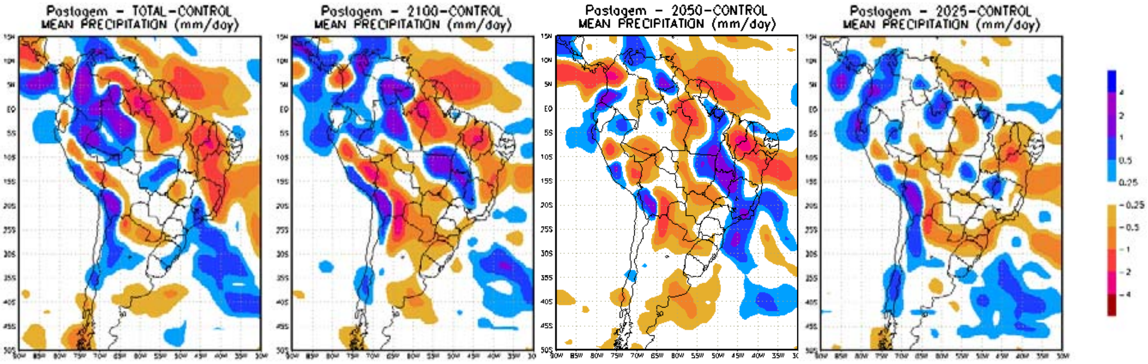
Figure 3 – Monthly distribution (January to December) of the area average (6°S-6°N / 63°W-45°W) of mean surface temperature (°C). Black line is for control case, dark blue line is for 2025 experiment, green line is for 2050 experiment, light blue is for 2100 experiment and red line is for deforested case.



(a) (b) (c) (d)

Figure 4 – Mean evapotranspiration differences (mm/day) between 12-month means (January to December) of deforestation and control cases (deforested – control) for South America: (a) deforestation case – control; (b) 2100 experiment – control; (c) 2050 experiment – control; (d) 2025 experiment – control.

The annual precipitation was reduced by 14.5% for the deforestation case for annual average (~400-900 mm/year – figure 5). This result is in agreement with results of earlier simulation experiments (Lean and Warrilow-1989; Nobre, et al.-1991; Henderson-Sellers et al.-1993; Lean et al.-1993, Sud et al.-1996, Lean et al.-1996, Manzi and Planton-1996, Rocha et al.-1996, Hahmann and Dickinson.-1997, Costa and Foley-2000, Rocha-2001, Werth and Avissar-2002, Voldoire and Royer-2004 and Correia-2005). For other experiments the precipitation decrease (relative to the control case) are: 2.2% for 2025 experiment, 8% for 2050 experiment and 13.2% for 2100. The changes in precipitation for 2100 experiment e deforestation case shows reduction in simulated precipitation in eastern Amazonia and increase in the western side of Amazonia. Figure 6 shows the 12 month averages for 6°S-6°N / 63°W-45°W, and the reduction of precipitation is more evident between June to November.



(a) (b) (c) (d)

Figure 5 – Mean precipitation differences (mm/day) between 12-month means (January to December) of deforestation and control cases (deforested – control) for South America: (a) deforestation case – control; (b) 2100 experiment – control; (c) 2050 experiment – control; (d) 2025 experiment – control.

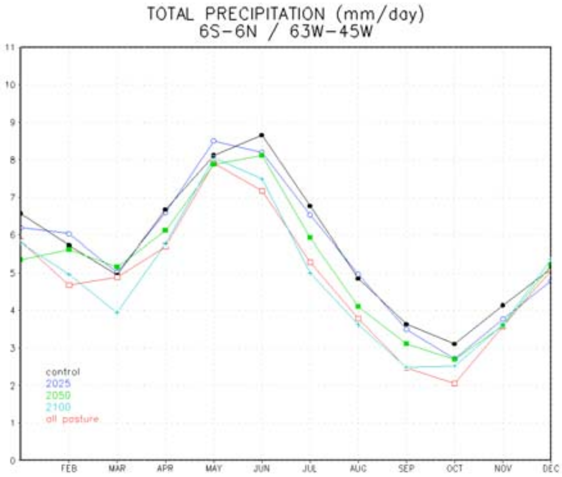


Figure 6 – Monthly distribution (January to December) of the area average (6°S-6°N / 63°W-45°W) of mean surface temperature (°C). Black line is for control case, dark blue line is for 2025 experiment, green line is for 2050 experiment, light blue is for 2100 experiment and red line is for deforested case.

The reduction of the vegetation cover caused an increase in runoff, but not caused a decrease in soil moisture, on the contrary, there was an increase in soil moisture in all experiments relative to the control case. This is because the reducing evapotranspiration that is associated with the reduction of roughness, that decrease the surface latent heat fluxes through the decreased in drag coefficient (Hahmann and Dickinson, 1997; Oyama, 2002) when replaces a tropical forest by pasture, and this may to drive a reduction in precipitation. By reducing evapotranspiration, deforestation results in less water being pumped in the atmosphere, thereby contributing to the decrease in precipitation. According Foley et al. (2003), the reduction in these huge cleared areas is also a consequence of the changes in the energy and water balance. The reduction in absorbed solar radiation and the increase in surface temperature both lead to a decrease in the net radiative heating of the land surface, defined as the difference between absorbed solar radiation and outgoing longwave (infrared) radiation. This leaves less energy to fuel atmospheric circulation, which ultimately results in a cooling of the upper atmosphere, followed by subsidence and less precipitation over the deforested region (Eltahir, 1996). Additionally, replacing a tropical forest by pasture there is an increase in albedo (tropical forest – 0.12/0.14; pasture – 0.17/0.19) and this leaves to reduction in the net radiation of the surface and surface latent heat flux (Hahmann and Dickinson, 1997), which results in a decrease in precipitation (Oyama, 2002). Charney (1975) and Charney et al. (1977) have showed that the impact of a 5% increase in continental albedo is a reduction in precipitation of between 5% and 20%. In this work, for replacing all forest by degraded pasture, there is a increase about 5% in continental albedo and a reduction about 14,5% in precipitation.

4 – CONCLUSIONS

We used CPTEC global atmospheric model to assess the effects of Amazonian deforestation on the regional climate. We used four projected distinct scenarios of land cover change: 1) land cover scenario for year 2025; 2) scenario for year 2050; 3) scenario for year 2100 and 4) replace all the Amazonia rainforest by pasture (deforested case). The results shows increase in surface temperature: 0.8 °C for 2025 experiment to 2.5°C for deforested case, a decrease in evapotranspiration: 4.4% for 2025 experiment to 16.1% for deforested case and a decrease in precipitation: 2.2% for 2025 experiment to 14.5% for deforested case.

Recently, Oyama and Nobre (2003) showed the existence of a second stable biome-climate equilibrium with savannas covering eastern Amazonia and semi-deserts in Northeast Brazil. In Amazonia, natural ecosystems have been under increasing land use change pressure. These large-scale land cover changes could cause warming and a reduction of rainfall by themselves in Amazonia and catastrophic species losses.

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